ALEXEI KRYLOV

From the Bonfire to the Reactor

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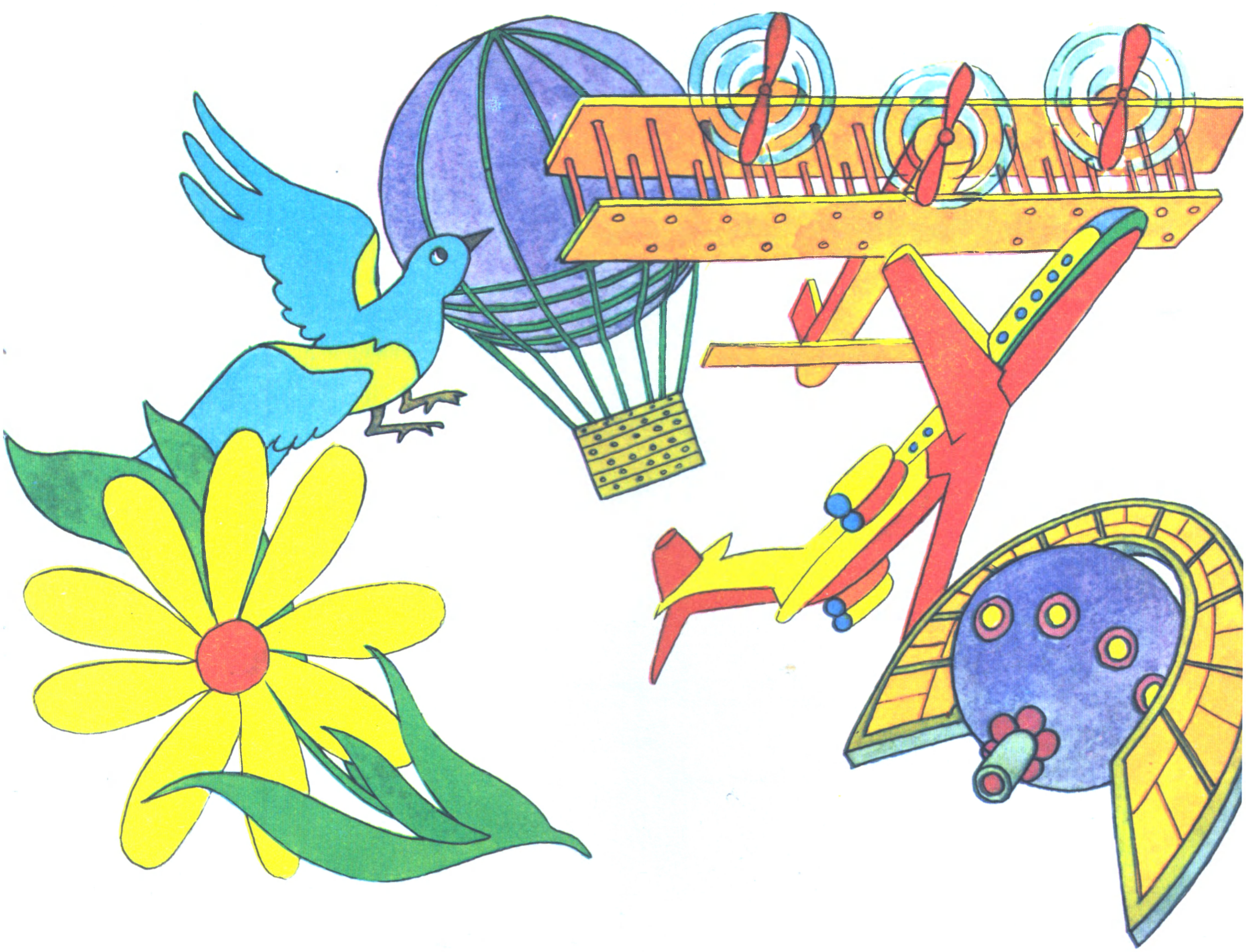
Why do airplanes fly?
What makes cars and trains run?
Why is electricity provided to our homes and to factories?
Why do people eat? Indeed, why and what for?

Drawings by
Andrei Platonov
Translated from the Russian by
Doris Bradbury



А. Крылов

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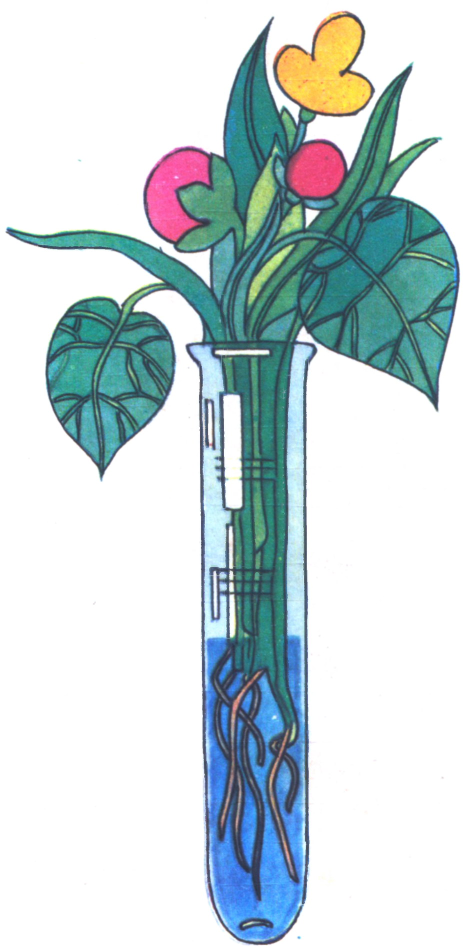


Al Fe_2O_3
H_2O SO_2
C_6H_{14}
O H_2SO_4

Have you ever seen how houses are built? The builders take the bricks or cement blocks, lift them, turn them around, align them, and lay them in the right place.

Both bricks and houses are man-made. Various machines help men in this task: cement-mixers, conveyors, cranes, and lorries.

Both men and machines need strength in order to work—carrying, lifting, rolling, and turning over the needed materials. A lot of strength.

Where does man get this strength? Everyone knows the answer to this "from the cradle", as the saying goes. Your mother and grandmother probably told you over and over again: "If you don't eat, you won't grow up big and strong." That is very true. Man receives his strength through food. Food also provides him with the "bricks", the "building material" out of which his body is made.

But where do machines get their strength? What is their source of "nourishment"? We could list the following sources: gas, oil, petrol, coal, peat, kerosene, and electricity.

"Wait a minute," you may say. "How is a tasty hamburger or a glass of milk like a barrel of oil or electricity?" At first glance, they are not at all alike. But if you think about it for a minute, they have a lot in common.

A hamburger, milk, a slice of bread and butter, petrol, gas and electricity all provide a charge of strength.

This invisible charge is called ENERGY. Energy is needed by everything, everywhere—to build a diesel locomotive and set it in motion, to sew a shirt, make a briefcase, and launch a rocket. It is needed for blood to flow in the veins, for muscles to be strong and for clear thinking.

...Our distant ancestors had a hard time. They were surrounded by an incomprehensible, hostile world. Natural disasters, famine, cold, and wild animals threatened them at every step. And in his struggle against these powerful enemies ancient man had only his own strength to draw on.

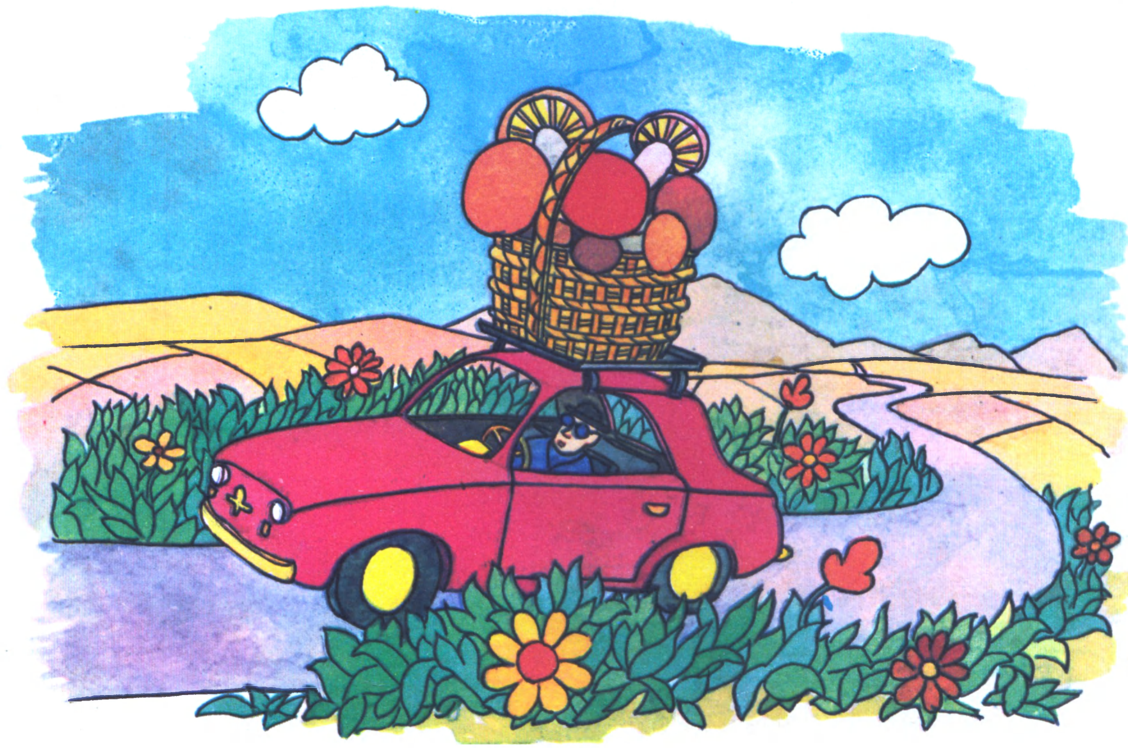
It was not only man's agile hands or swift feet that helped him

in this struggle, for the predators also had swift feet. Man's main weapon was his sharp, tenacious mind.

...A tree is struck by lightning and catches fire. The wind fans the sparks and a nearby tree also catches fire. Then a bush catches fire and tongues of flame race across the grass. This is how a forest fire starts. Panic-stricken animals flee from the forest. Birds fly high up into the sky. Only a small group of squat, sturdy men clad in animal skins hold their ground on the edge of the forest. They are eager to flee too, but they know that the fire will soon die out and heaps of golden coals will remain on the site of the fire to give off heat during the cold night to come. And beneath the layer of ashes they will find soft, cooked roots...

Then someone thought of taking coals from the fire site and throwing a fistful of dry grass on them. This was the first bonfire. Man had tamed fire and become stronger.

Why? Because he now had a NEW SOURCE OF ENERGY, a powerful ally in his struggle against hunger, darkness, and wild animals.



I can tell you one thing right away: no one has ever seen energy. It has no colour, taste, or odour. It cannot be touched, as, for instance, a brick can be touched. There is only one way to "see" energy—when it is at work.

Today we know nearly all the secrets of this invisible force.

It turns out that there is no such thing as "just energy". There are five types of energy: CHEMICAL, THERMAL, MECHANICAL, ELECTRICAL, and, finally, ATOMIC, or NUCLEAR ENERGY.

For the moment we are not going to jump ahead and discuss their "characters" in detail. We shall get to everything in time. Right now we are only going to talk about their most outstanding features and abilities.

We already know their first, most important feature. All forms of energy can "work". Energy used to be simply called "work".

Energy's second feature is truly magical! Energy can be changed from one form to another. Chemical energy can be transformed into thermal energy. Thermal energy can be turned into mechanical energy, and so forth.

Men have been using this amazing feature for a long time. They have designed and built many different machines which change the form of energy.

It often happens that more than one machine is needed to carry out the desired "transformation". When needed, machines can be organised into a "relay" chain. The machines then transmit energy to each other, just like handing on a baton in a relay race. True, in a real race the baton remains the same and only the runners change, while in our race both the runners (the machines) and the baton (energy) change. Each machine "receives" energy

in one form from the preceding machine and transmits it in another form to the next machine.

There are many such chains on earth: at electric power stations, on ships, and elsewhere.

Nearly all forms of energy are transformed into MECHANICAL energy, for this is the form men need most. It sends trains racing along the tracks, enables airplanes to fly, sews shirts, and assembles cars and excavators. The mechanical energy provided by our hearts sends blood coursing through our veins, and our muscles' energy enables us to move, write, and work.

So far, so good. A part has been turned on a lathe or a shirt has been sewn. But where has the energy that helped us in this task gone? What has it become? Has it become the machine part, the shirt, or something else? No, none of these things.

Whatever we may do with it, energy always remains energy. It only changes from one form to another.

After energy has served man by forging steel, trasporting freight, or showing a television programme, it always becomes heat, or THERMAL energy.

For instance: a locomotive races along, dragging a long chain of carriages behind it. As it tears past, the air whips against the train's windscreens, pulling at each step and creating friction as it hits the train's sides and roof. It is an obstacle to the train's movement. The wheels knock beneath the carriages as they whirl along the tracks, also creating friction. Nearly all the train's energy is lost in this friction.

And friction warms things. This is very easy to demonstrate. Rub the palms of your hands together and you will feel the warmth immediately.

Does this mean, then, that as the train travels along the tracks it warms the tracks and the air? Yes, it does. This warmth then goes into the upper atmosphere and further into outer space.

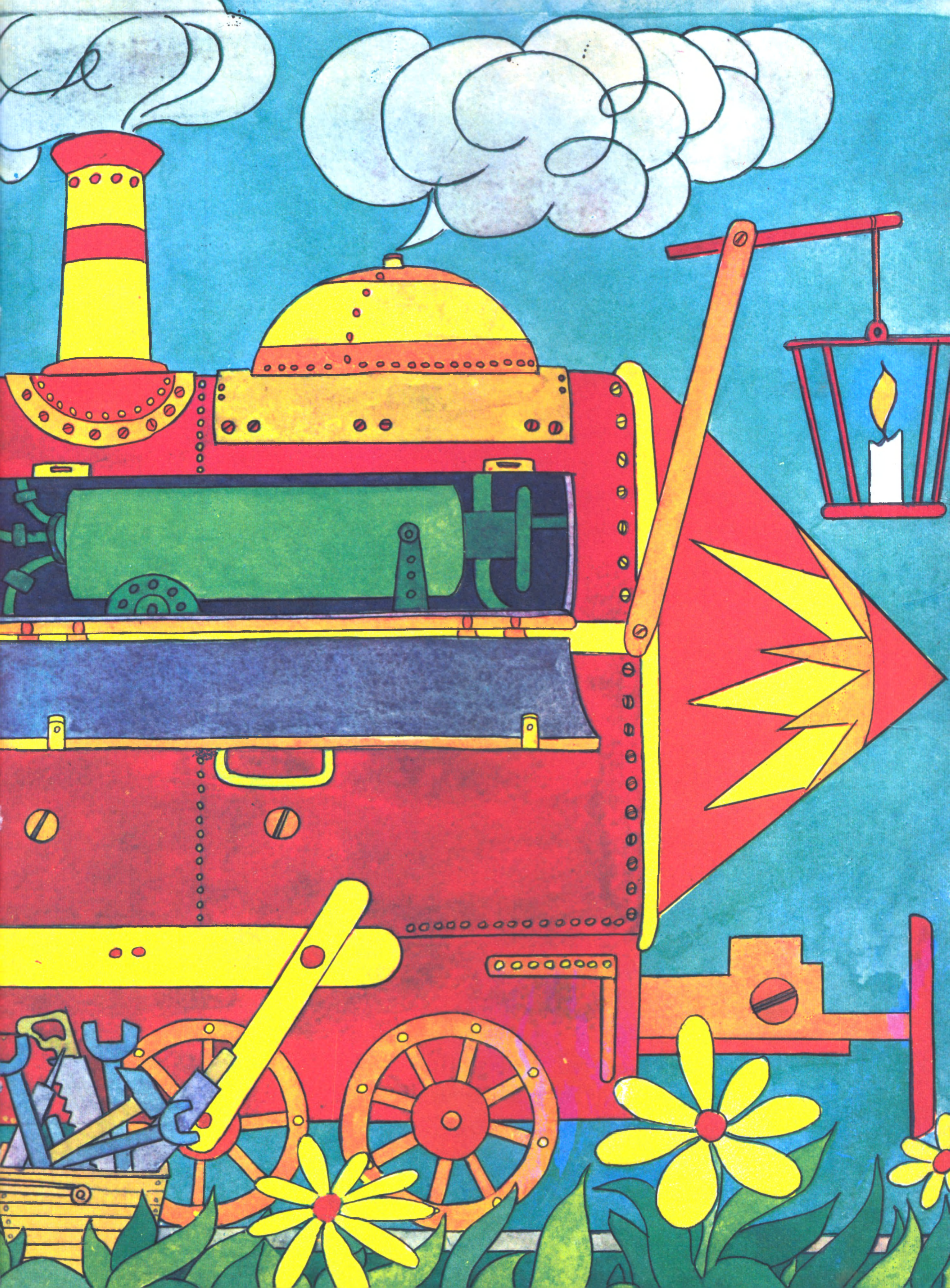
The same thing happens to a car. Touch a car's wheels after

it has been driven for a long time. They are really hot!

What is happening then? Does Earth "warm" outer space? Of course. But outer space does more than just take energy from Earth. It also sends us its own, solar energy. This is stored up in plants and is transformed into CHEMICAL energy. Sooner or later plants die, and their remains turn into oil, gas, coal, and peat.

Fuel is the major source of energy on Earth today. Or, to be more exact, it is the major source for the time being.

By burning fuel, we obtain nearly all the energy we need. The fuel burned yearly in the boiler-rooms of power stations, the engines of cars, ships, and airplanes, in smelting furnaces and in rockets produces enough heat to boil all the water in the Black Sea.



How Does Heat Work for Us?

A long time ago a young boy was sitting by a blazing fireplace. A pot containing soup hung over the fire. The water bubbled and boiled. Steam pushed its way out from under the pot's lid, making it jump and rattle.

"Why does it jump?" the boy wondered. He took a cloth and tried to hold the lid down tightly, but he could not keep it down. Some strange force continued to push it upwards. This boy's name was James Watt.

People have boiled water since the dawn of time. Soup, meat, roots, and vegetables have always been boiled in kettles, and the kettles and saucepans have always been covered with lids so that the water would come to a boil more quickly.

When the water in a saucepan boils, it turns into steam. And if the saucepan is covered with a good, tight lid, more and more steam builds up beneath it. It pushes in all directions, creating pressure on the water, the sides of the saucepan and, finally, on the lid. It searches for a way out. Finally the steam lifts the lid and flows out into the air. Then the lid slams shut, and the steam is caught inside again. Once more it builds up and tries to push the lid up. You have probably seen this many times in the kitchen. James Watt saw the same thing two hundred years ago.

Force is needed to lift a stone, a pail with water, or even the lid on a saucepan. This means that the steam pushing up on the lid possesses force. Scientists already knew about this. More than a hundred years before Watt was born, two English mechanics, Thomas Newcomen and Thomas Savery built engines which made use of steam's force. Steam engines pumped water out of coal shafts, pulled wagons with coal, and lifted weights. But they were weak, cumbersome, and had "voracious appetites". Each of them "ate" a whole mountain of coal and "drank" tons of water during a day's work. Their useful work was very limited by comparison.

When James Watt was sixteen years old, he started work at a workshop which repaired pumps, steam engines, and looms. He became an excellent mechanic, and soon devised a plan for a wonderful steam engine.

This engine was like a "saucepan" with three lids. Two were fixed down tightly, while the third—the inner lid, a piston—was free to move. Steam entered the "saucepan"-cylinder through an opening from above or below the piston, pushing it up or down by turns. The piston was joined to either a pump or a lathe. When the piston moved, the pump began to work or the lathe began to turn.

The steam was obtained by boiling water in a special steam boiler, and went through a pipe to the engine.

Watt's engine was far better than any other. It used less coal and water, it worked faster, and it was more efficient.

Watt's engine was the beginning of the "steam age". Factory chimneys began to smoke and the first steamboats sailed the rivers and seas. They no longer had to wait for wind to fill their sails. This steam engine enabled ships to sail anywhere without sails.

The first locomotive-driven trains now raced along railway tracks. They could transport a far larger load than a hundred horses all pulling together. The steam car was invented. The world changed before men's eyes.

But this did not come about suddenly. Even the most intelligent people did not realise immediately what a mighty force they now had at their disposal.

Once a modestly dressed young man obtained an audience with Napoleon and unfolded before him draft designs for an unusual ship—one without sails or high masts. The ship had only a long, thin pipe rising from its middle. Black clouds of steam poured out of this smoke-stack. Along the ship's sides there were enormous wheels. The ship looked terribly ugly for the time. Napoleon threw its inventor out without even listening

to him. Twelve years later, as the French emperor was being sent into exile on the Ile Ste. Hélène, he saw a ship appear to the right of his own vessel.

Can you guess what it was? Of course, it was this same ship with its towering smoke-stack and enormous wheels. It proudly bore the flag of England—Napoleon's mortal enemy. Fulton, the ship's inventor, had gone from Napoleon directly to England, where his invention had been appreciated immediately.

Steam engines were built in Russia by two outstanding mechanics, Efim Cherepanov and his son, Miron. Their engines were put to work in ore-fields and small factories. In 1834, Russia's first railway with a steam-driven locomotive was built in the Urals.

There was no machine to surpass Watt's machine for a century. Then one day the following happened.

A sea parade was organised in England. The ships had taken their places and their crews stood on the decks. At that very moment a tiny uninvited vessel appeared out in front. The admiral gave the order to pursue the tiny vessel and drive it into harbour. The swiftest ship set off in pursuit, but something entirely unexpected happened: the tiny vessel easily eluded its pursuer.

The captain of the vessel, an engineer named Charles Parsons, had installed a new engine—a steam turbine—on his yacht.

While a steam engine is similar to a pump—up-down, up-down—a turbine is similar to a top surrounded by blades. "Turbo", incidentally, means "top" in Latin. Steam flows from a pipe ending in a nozzle, striking the blades and making the turbine spin.

Parsons placed his "top" on its side and fastened a screw propeller to the turbine's shaft. When the turbine turned, the screw propeller also turned, and the vessel sailed swiftly ahead.

Today turbines do more than just sail the seas. Their main task is at power stations, where heat is turned into electricity.

Yet another type of engine appeared a century ago. It also obtained its energy from fuel, but this fuel burned in the engine, rather than in the furnace of the steam boiler. It was therefore called an internal combustion engine.

This engine is similar to a steam engine in that it has a cylinder and piston, but it does not need steam, a boiler, or thick steam pipes. It works in the following way.

Liquid fuel—oil or petrol—is injected into the cylinder, where it catches fire and gives off red-hot gases. They exert pressure on the piston and push it. The piston turns the shaft, to which a wheel or screw propeller is attached.

The inventor of this engine was a German engineer named Rudolf Diesel. Workers and engineers at the Russian Diesel Factory in St. Petersburg built their own engine at about the same time. It was smaller, lighter and, most important, it operated on cheap fuel—oil.

Today the internal combustion engine is the major type of engine used in transportation. Take a good look around you. Motor ships sail the seas and rivers. Diesel locomotives travel along the railroads. Cars drive along the roads and streets. Helicopters and small, swift planes dart across the skies. Tractors and harvesters work in the fields. All of these forms of transport sail, drive, and fly thanks to this simple, reliable engine.

The "grandfather" of the modern automobile was built in France two hundred years ago. A steam engine and boiler were installed in it. The test drive took place in Paris in a very festive atmosphere. Policemen walked ahead of the car, dispersing the crowds of gawkers. The driver rode behind them in a cloud of smoke and steam. Barrels of water and crates of coal followed along behind on carts. Every ten minutes the whole procession stopped as coal was thrown into the furnace and water poured into the boiler, and then set off again. The journey did not last long. The inventor, who was driving the car, could not control the

driving wheel. His car ran into a wall and exploded. Today, this car designed by Nicolas Cugnot has been repaired and cleaned, and occupies a place of honour in the Museum of Transport in Paris.

The first real automobile was made in 1886. A German mechanic named Gottlieb Daimler built it with his own hands. He used an ordinary carriage for the car's body and installed a petrol-driven engine of his own design in it.

The first airplane, which was built by a Russian naval officer, Captain Mozhaisky, was also too heavy to fly. Its steam engine weighed so much that the plane was only able to gather momentum and leap into the air a few times. Mozhaisky himself understood very well that no one could fly far on a steam machine and that an airplane needed another engine—a lighter and more powerful one.

In 1902 an airplane with a petrol engine took off. It had been built by the Wright brothers, Orville and Wilbur, two young American mechanics. Their first flight ended in failure. Wilbur, who was the first to fly, turned the nose of the plane upwards too sharply. It lost speed and crashed. Fortunately, no one was injured. Two weeks later, Orville lay down on the wing of the plane; it was the only way to control it. The engine was started, the plane gathered momentum, and it took off. True, this flight only lasted 17 seconds...

The internal combustion engine inherited a serious defect from its "grandmother", the steam engine. The pistons in the internal combustion and steam engines work in the same way: up-down, up-down, shaking the engine. The more powerful the engine, the more it shakes. It can even break apart beneath the blows from its own pistons.

But the turbine does not have any pistons hammering away at it. Nor is there any danger of its breaking apart. Turbines can therefore be very strong and powerful.

This was shown in practice recently in the Soviet Union at the

Leningrad Metal Factory. A very unusual steam turbine was built there. It alone is more powerful than all the turbines in operation in Russia before the 1917 Revolution.

The engineers thought over the problem this way. The internal combustion engine is lightweight and simple, but it cannot be very powerful. On the other hand, there is the turbine, a marvellous engine, but it needs a boiler. The modern steam boiler is as high as a five-storey house. It also needs a cooling unit, pipes, pumps, and so forth.

"Would it be possible to combine the lightness and simplicity of an internal combustion engine with the power and speed of a turbine?" wondered the engineers. "The hot gases could turn the 'top', rather than pushing the piston." And so an engine of this type was designed. It was built in the Soviet Union in 1939 and called a gas turbine.

The gas turbine is similar to a steam turbine. Only it is not operated by steam, but by a stream of hot gas.

This is a very light, powerful, and speedy engine. It would seem to have been designed for aviation. Gas turbines are now in operation on nearly all planes.

If you have ever fired a real rifle, you probably remember how the gun's butt hits your shoulder as the gun is fired. This is called "recoil". Where does it come from? When we pull the trigger, the hammer hits a piston. This blow creates a spark which ignites the powder in the cartridge. The gases released by the powder strike the back end of the cartridge or the buckshot hard, pushing out in all directions. The bullet flies out of the gun's barrel, and the gunman receives a blow in the shoulder. The force which strikes both the rifle and the hunter is called reactive force.

What if you remove the bullet from the cartridge and shoot a blank? Will there be a recoil? Yes. And what if you introduce powder or fuel into the "rifle", not in small portions as in an ordinary rifle, but constantly? Or what if the charge is made to

burn up not immediately, but gradually? Then the reactive force will constantly exert pressure on the "rifle", pushing it away. This is the way a reactive engine is made.

Reactive engines are made of durable steel and are used in airplanes and rockets.

Airplane engines operate on liquid fuel—kerosene. Rocket engines can operate on either liquid or solid fuel. The construction of an airplane engine is totally unlike a rocket's engine. This is logical, since they operate in different circumstances.

Airplanes fly close to the Earth's surface, in its atmosphere. In other words, they fly in air, which is needed to burn fuel. Airplane engines have a special part, an airtake inlet. During the plane's flight, its broad, open "mouth" gulps in the air. Then the air is tightly compressed and enters the combustion chamber. Kerosene is injected into this chamber, and catches fire from the high temperature. The hot flow of gas explodes from the nozzle, pushing the engine, and the airplane with it, ahead.

Rockets fly in airless outer space far from the Earth. This is important—*airless* space. Yet their fuel has to be burned.

That is why rockets take their fuel and air—or, more accurately, their oxygen—with them.

If a rocket engine operates on liquid fuel, it needs two tanks in order to fly. One contains fuel and the other oxygen. The fuel and oxygen are injected into the combustion chamber—and from here on you know the rest.

In fact, there are several tanks on rockets. When fuel and oxygen in one pair run out, it is "thrown overboard", and fuel and oxygen are taken from the next pair. When this one empties, the next is brought into operation.

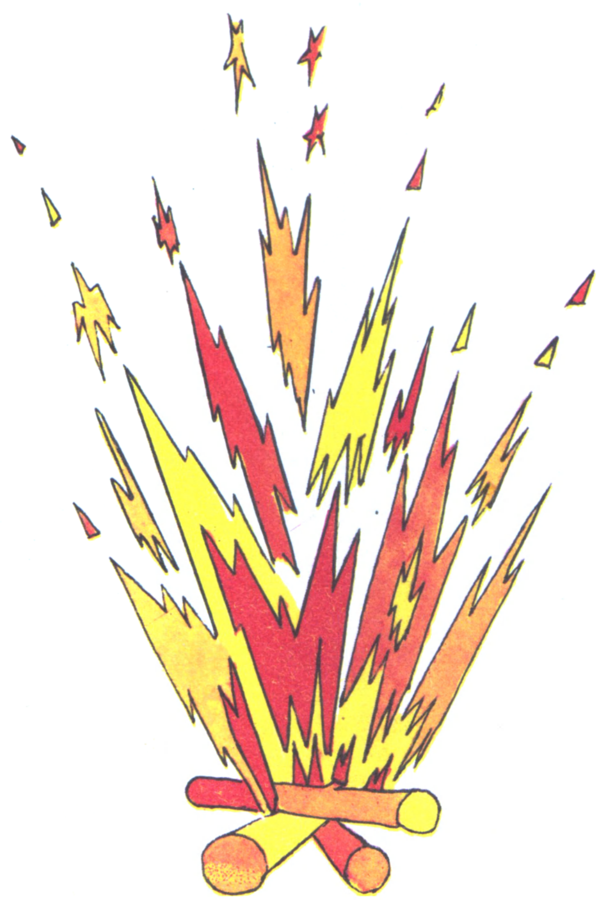
Do you remember the news bulletins when satellites or space ships are launched? "The first stage has separated normally... The second stage has separated... The third stage..." These stages are the tanks for fuel and oxygen.

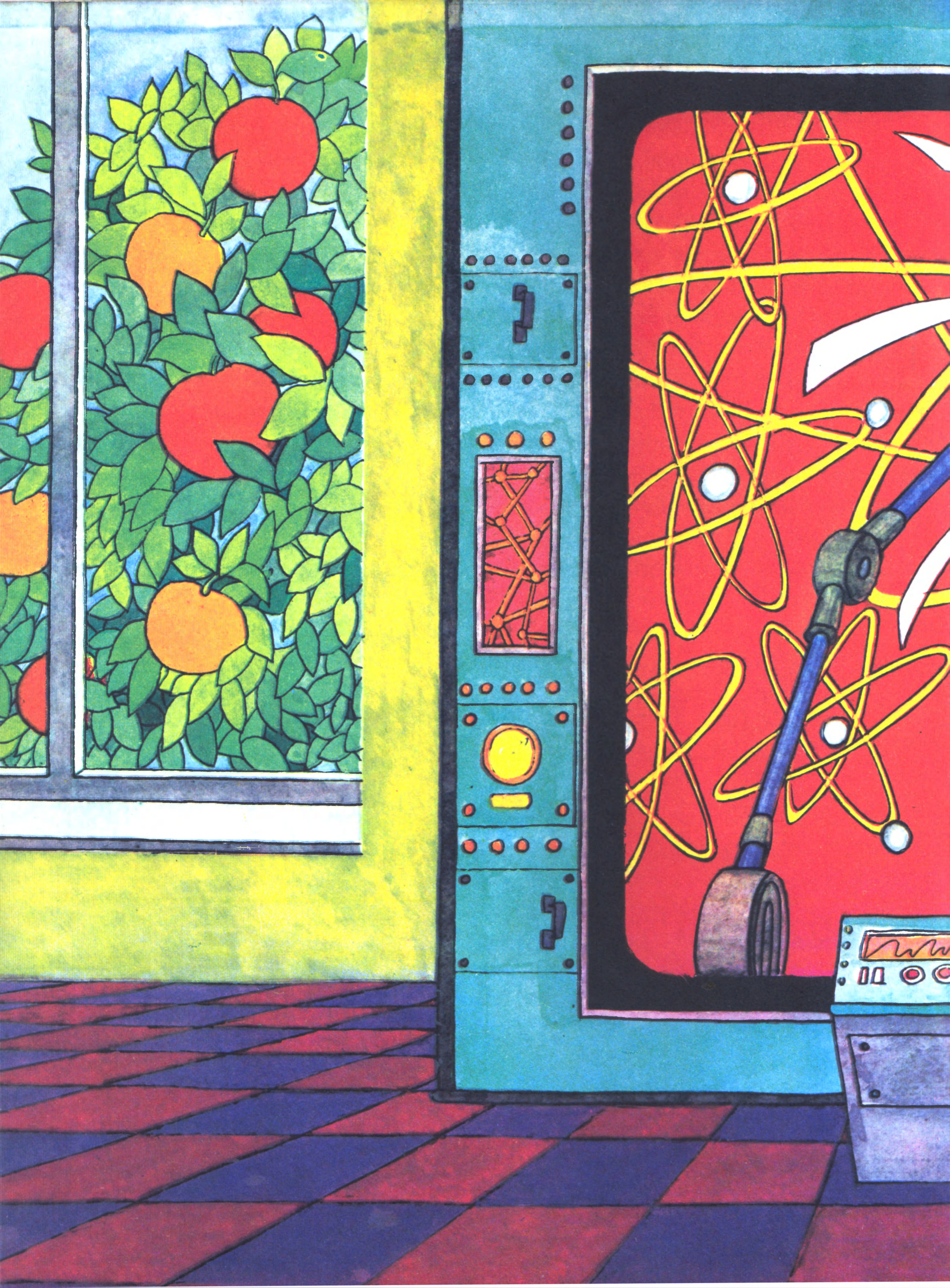
Solid fuel is mixed with oxygen while the rocket is still on Earth. It burns right in the tank. When one tank "burns up", it separates and is thrown overboard. Fuel then begins to burn in the next tank... These are also rocket stages.

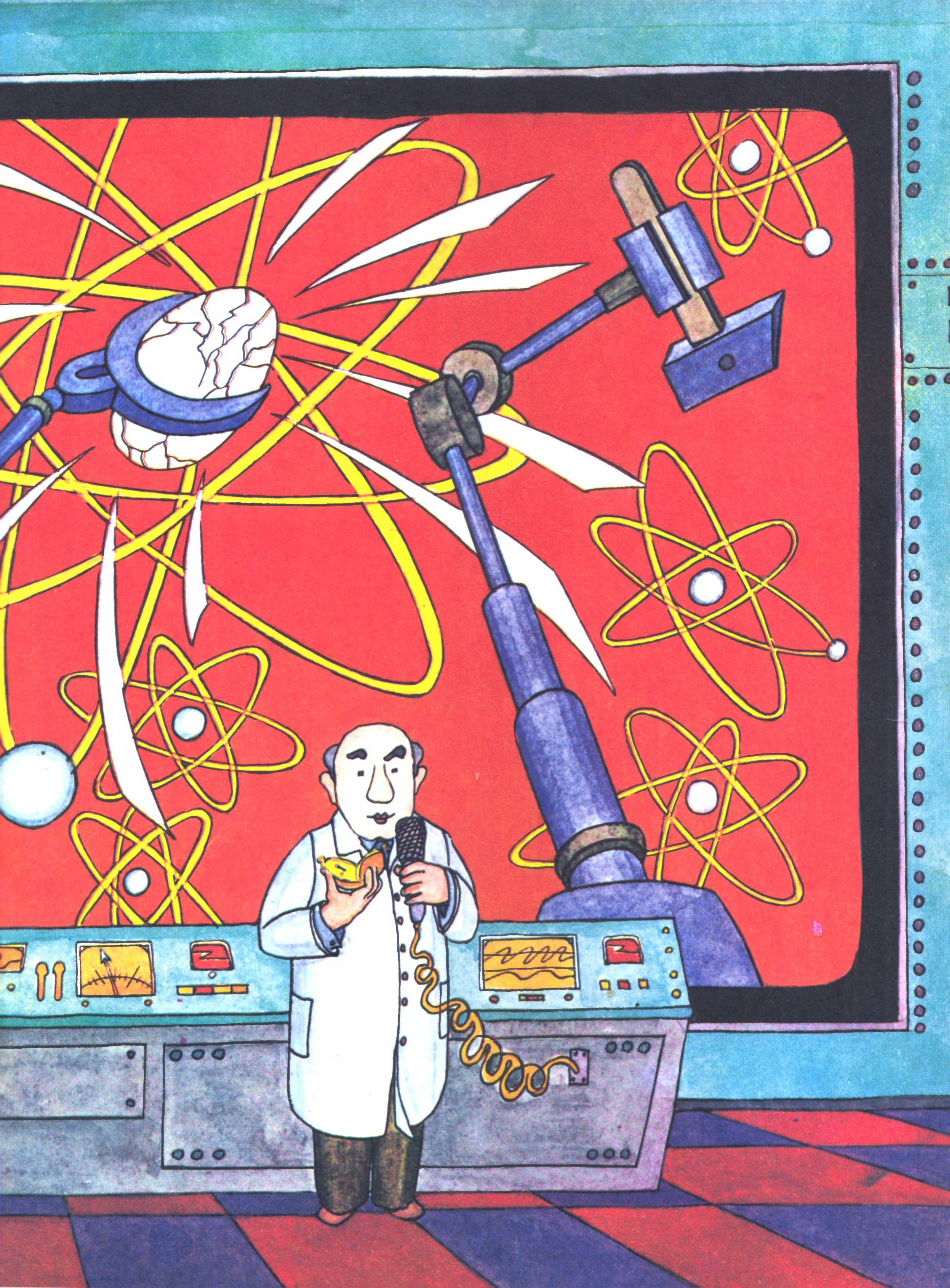
All the engines we have been discussing are close relatives. They all need fuel in order to operate. As they burn up fuel they give off thermal energy. That is why machines are called thermal.

There is still a great deal of fuel on earth, but our reserves are diminishing year by year. Experts say that we have enough fuel for another hundred or hundred and fifty years. That is, if we use it economically and carefully. This means that people must make better use of old sources of energy, as well as searching for new sources.

What kind of sources? We shall discuss them further on.







30 How Much Does a Kilogramme of Uranium Weigh?

Have you heard about nuclear power stations and nuclear ice-breakers? You have probably both heard and read about them. Nuclear power stations produce electricity, and nuclear ice-breakers take caravans of freight vessels through the Arctic Ocean.

People learned how to use the energy in the atom only recently. The world's first nuclear power station was put into operation in the Soviet Union in 1954 in the small town of Obninsk near Kaluga. The world's first nuclear ships appeared even later.

Yet the word "atom" has been known to men since time immemorial. Over two thousand years ago a learned man named Democritus lived in ancient Greece. He thought a great deal about man's natural surroundings. He wondered what water, stones, trees, flowers, animals, and other things were made of. He did not have any complicated apparatus such as helps scientists today. But Democritus had a brilliant idea. He believed that everything in nature was made of tiny units, just as a house was built of bricks. Only these "bricks" in nature were invisible to the naked eye and Democritus believed they were the smallest units of matter in the world. They could not be broken down into smaller units. Democritus called these tiny particles "atoms", which means "indivisible". Only many centuries later did it become clear that Democritus had been mistaken.

A hundred years ago a French scientist named Henri Becquerel was clearing up his laboratory before going home. He put his test-tubes and flasks for chemical experiments away in a closet. He placed his photographic plates wrapped in thick black paper on a shelf. Then he glanced one last time at the clean, shining tables and noticed a few pieces of a substance he was studying. This substance was called uranium. Becquerel was in a hurry and, as he gathered up the tiny pieces and tossed them on the shelf, one piece fell onto the package containing the photographic

plates. Turning out the gaslight, Becquerel closed the door and left.

The following day Becquerel flicked the tiny piece of uranium off the package, and then took a photograph on the plate. When he developed it, it turned out it had been pre-exposed and spoiled. There was a black spot on the film where the piece of uranium had lain. The scientist was amazed, and repeated his actions, this time deliberately. Again he saw a clear "picture" of the piece of uranium on the photographic plate.

Two other scientists, Pierre and Marie Curie, attempted to solve this mystery. They experimented with various substances and discovered that radium and polonium also produce the same result. But why? There could only be one explanation. That particles of some sort flow from the very depths of the "indivisible" atoms. It was these particles which exposed the plates. And that meant that the atom was not the smallest unit, that there must be even smaller particles.

Today we know almost for certain how the atom is structured. Imagine a heavy drop of honey surrounded by a cloud of midges. The midges whirl around the drop, unable to tear themselves away from it. We would see approximately the same picture if we were able to examine an atom of any substance. At the centre is the heavy "drop", the nucleus. Whirling around it, like light, mobile midges, are electrons. They circle the nucleus as if they were bound to it. However, they do not fly round it chaotically, like midges, but each follows its own path—its orbit.

This is not everything, though. The nucleus is also made up of tightly-packed particles. They are called protons and neutrons. The nucleus is like a spring tightly coiled by a string and, like a spring, it contains tremendous strength. If the spring is to straighten out and release its hidden energy, the string must be cut. If the nucleus is to release its energy, it must be destroyed, and the invisible threads binding together the particles must be cut. Then they fly off in all directions, releasing their energy into the surrounding space.

The nuclei of "heavy" substances—uranium and plutonium—are easiest to destroy (or split, as scientists say). These substances are called "heavy" because their nuclei contain a

great many particles. If a particle hits the nucleus, like a bullet hitting a target, this is enough to split it. The best "bullets" are neutrons—the same particles making up the nucleus.

The normal place for neutrons to be is in the nucleus. However, there are always "voyager" neutrons among the "stay-at-home" ones. They leave the nucleus and wander through the piece of uranium, like travellers on the road. Sooner or later a "voyager" neutron will encounter another nucleus. The nucleus splits from the force of the blow and two neutrons emerge from it. One way or another, they will inevitably split the next two nuclei. Now there will be four bullets in the piece of uranium. And so it goes on and on... One after another, the nuclei fly off in all directions, like splinters scattered by an axe-blow, giving off their energy. A lot of energy generates a lot of heat. One kilogramme of uranium generates as much heat as 2,000 tons of coal.

Isn't this wonderful! Only one or two lead boxes of uranium would be enough to furnish a large power station with fuel for an entire year. That is why nuclear power stations are built where there is no source of coal, oil, or peat near by.

The most important thing at a station of this type is the ATOMIC or, more correctly, the NUCLEAR REACTOR. This is an enormous metal cylinder enclosed at the top and bottom. It looks very much like a large saucepan or cauldron. Inside the cauldron there are rods of uranium and water-pipes. There are various instruments and mechanical devices on the outside of the reactor's top. Nuclei split continuously inside the uranium rods, and thus nuclear fuel is being "burned", heating the water in pipes to a high temperature. Pumps force the hot water into a STEAM GENERATOR—a machine which makes steam.

The construction of the steam generator is very simple: one pipe inside another. The inner pipe contains hot water from the reactor. The outer, water from the cooling unit running in the opposite direction to that in the inner pipe. The heat from the water flowing out of the reactor is transmitted to the cold water. When it reaches the boiling point, it turns to steam. The steam is conveyed to the blades of the TURBINE and it begins to spin.

Having given off its heat, the reactor's water returns to the

reactor, is heated up again, and once more goes to the steam generator. The ring along which it travels is called the FIRST CONTOUR.

Once it has turned the turbine, the steam goes to the cooling unit, where it cools and becomes water again. The water flows again into the steam generator and is again turned into steam... This second ring conveying the water and steam is called the SECOND CONTOUR.

The REACTOR, STEAM GENERATOR and TURBINE together with the cooling unit are called a NUCLEAR ENERGY INSTALLATION. This installation is run by automatic machines and men—the machine operators.

Installations of this type are at work at nuclear power stations and on nuclear ice-breakers. Turbines at the power stations turn the atom's energy into electricity, and the turbines on an ice-breaker turn it into motion. Powerful installations of this type help ice-breakers guide caravans of vessels through the thickest ice. In August 1977, the Soviet ice-breaker, *The Arctic,* made its way to the North Pole through solid fields of ice. No other ice-breaker before had ever been able to do this.

We would not be surprised if our readers had at least two questions to ask at this point.

First question: "Why does water in the second contour boil and turn to steam? And why is there no steam in the first contour?"

Second question: "Why are two contours needed, anyway? Why can't the steam be made directly in the reactor?" After all, there is enough heat there to make steam.

The first question is easy to answer. Water cannot boil in the first contour because it is too highly compressed. The higher the pressure, the higher the boiling point of water.

To answer the second question we must go back a way.

Although uranium "burns" in a measured way, it is very dangerous to human beings. When the nucleus splits, a great many "fragments" and particles fly off in all directions at high speed. This flow is called radiation. Radiation is harmful to every living thing. That is why a reactor is always encircled by thick concrete walls. These walls are called "biological protection".

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The two water contours in the nuclear installations are also designed to protect people from radiation. The water flowing through the first contour is "infected" by radiation and, like uranium, it gives off particles. If this "infected", "dirty" water is turned into steam, then the pipes, pumps, and turbines will also become radioactive. That is why it was decided that the reactor's radioative water should be used to heat up the other water. The pipe's walls greatly hamper the flow of harmful particles, allowing the water in the second contour to remain pure, or almost pure. There is no need to build biological protection around the turbine and cooling unit. People can work alongside them safely.

Pierre Curie was the first to experience the effects of radiation. This courageous man held his hand over a piece of radium for several hours. Some time later a burn and a wound appeared on his hand. He was successfully treated, but people understood after this that caution was needed in working with radium and uranium.

Nuclear energy will help people in yet another important way. The earth's supply of fresh water is decreasing rapidly—ordinary water, which we drink and use for washing. Not because we are drinking more or bathing more, but because industry is using more and more water. It is needed to smelt iron, drill for oil, and produce electricity. Agriculture requires a lot of water, too. There are places on earth with a great deal of sun and fertile land, but without water. Canals are dug there and water pumped into them from rivers and lakes to quench the parched fields.

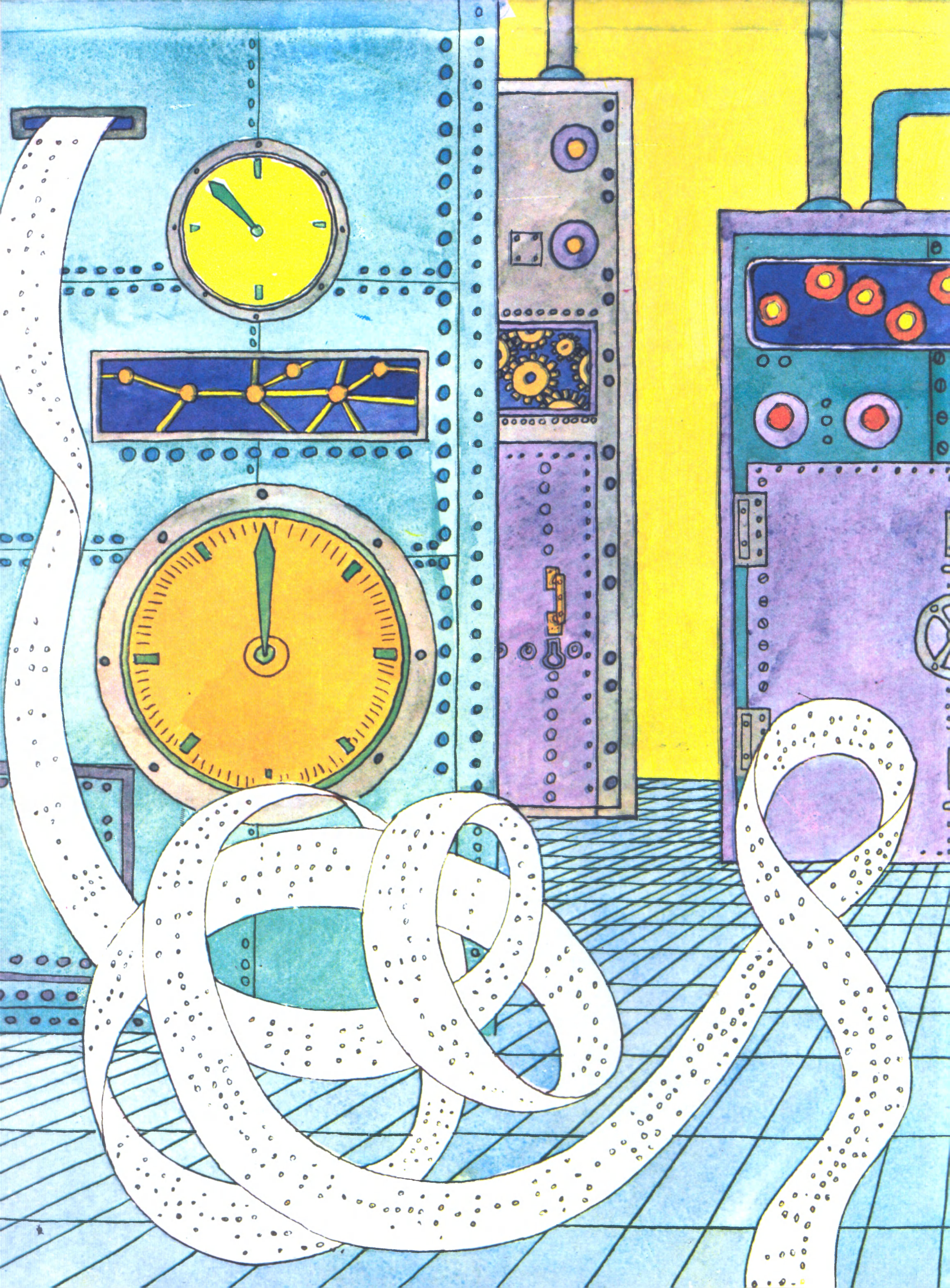
The earth's largest sources of water are its seas and oceans, but their water is salty. Salt water can be made into fresh water so that it can be used. This is very simple—the salt water is boiled and the steam which rises from it is collected in condensing units and cooled. The result is fresh water. It is then slightly salted "to taste", and is ready to be used for washing, drinking, or watering gardens and vegetable patches. The sediment is removed from the "kettle", and once again salt water is boiled in it. Even the sediment is a useful by-product. It contains many precious substances: manganese, sodium, potassium, and even a little gold.

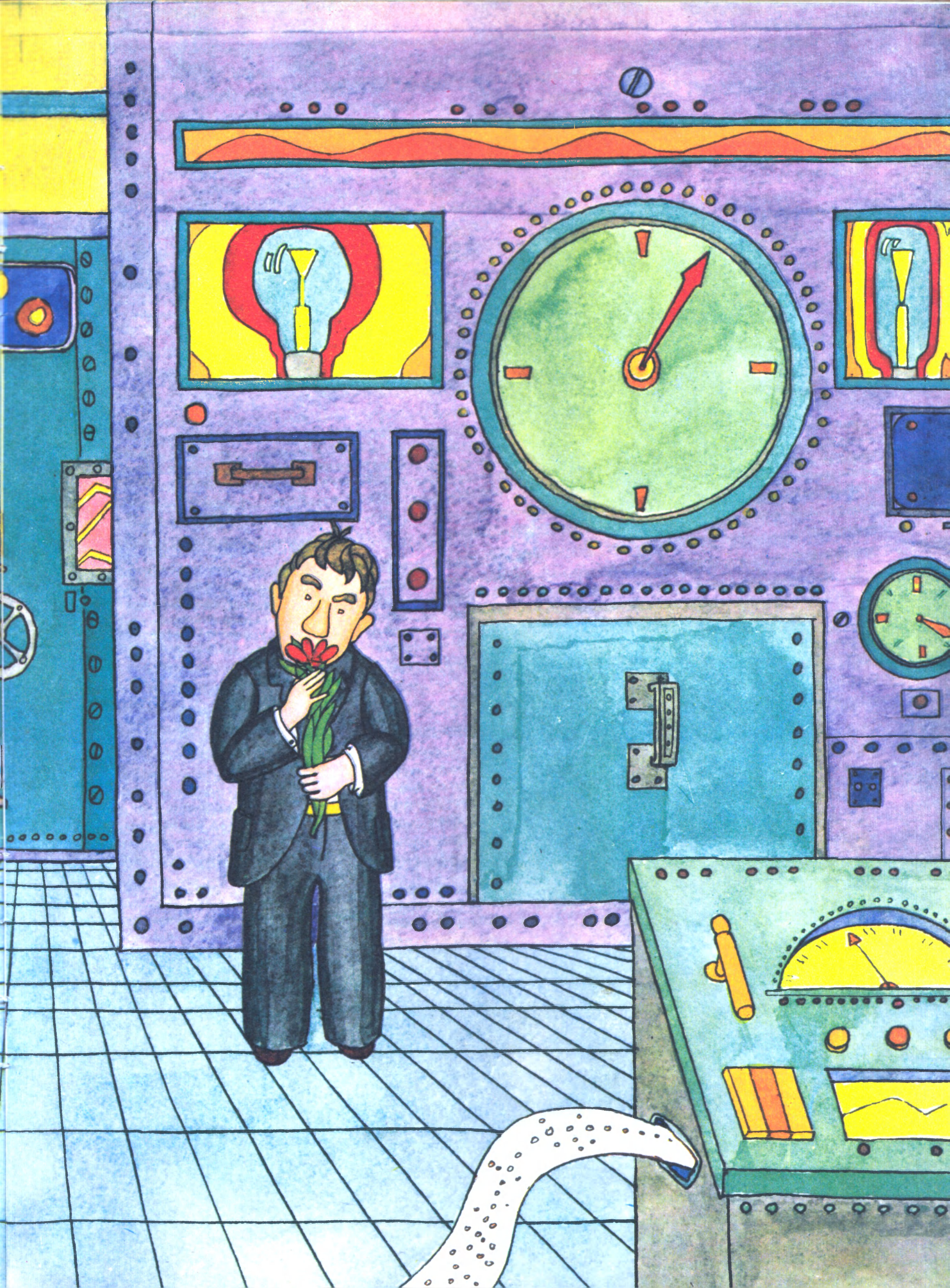
A lot of energy is needed to turn salt water into fresh water. This energy can be provided by nuclear power stations.

Shevchenko is a city located in the arid desert on the eastern shore of the Caspian Sea in the Soviet Union. One immediately visualises land as flat as a table, and parched streets devoid of grass or trees. But this would be wrong. Shevchenko has as much water as you could want. It has shady, tree-lined lanes and fountains, and is filled with flowers. All of these miracles have been made by human hands. This has been possible because Shevchenko is the site of a nuclear power station. Its power goes almost entirely to a powerful installation for producing fresh water. Thus, the city is provided with water, and industry with raw materials: salts of sodium, potassium, manganese, and many other useful substances.

Nuclear power stations at present produce much less electricity than thermal power stations. But soon, in twenty or thirty years, nuclear power stations will become the major force in energy production on earth. There are two reasons for this. Firstly, because there is increasingly less fuel available. Secondly, because it would be very unwise to burn it all up. A great many useful things can be made from oil, gas, and coal: artificial thread, for instance, and therefore shirts, coats, and furs; artificial materials stronger than steel; glass, cotton, machine parts, and many, many other things. On the whole, experts believe that by the year 2000 more than half of our electricity will be produced by nuclear power stations. And it will be ten times cheaper than that produced by thermal power stations.

Production of nuclear energy is growing quickly in the Soviet Union. Up to ten nuclear power stations are built during each five-year plan period.





Can Water Burn?

There is a Russian fairy-tale about "sister-foxes" who "took matches, went to the blue sea, and set fire to the blue sea". It burned fiercely and firemen tried to put it out "with pies, pancakes, and dried mushrooms". "Nonsense," you will say. "Water doesn't burn, whether it is sea water, river water, or lake water. On the contrary, water puts out fires." You would be right, although not entirely.

Water as such does not burn—that is correct. But the interesting thing is that one of the elements of which it is composed burns marvellously, and the other sustains fire. These elements are hydrogen and oxygen. But there is more to the story than this. Sometimes there are special hydrogen particles, twice as heavy as normal ones. Hydrogen of this type is called heavy hydrogen or deuterium. It is this element which makes man dream of an abundance of energy.

It has long been known that if two atoms of heavy hydrogen are joined together, the result is the nucleus of a new element—helium, and a great deal of energy is produced. One kilogramme of deuterium provides as much energy as 14 million kilogrammes of coal when burned.

Do you know how much deuterium there is in the ocean? Enough to last mankind 50 billion years.

However, it is very difficult to fuse two nuclei. Deuterium must be heated to a temperature of 200 million degrees C to do this! Only at this temperature can two nuclei of deuterium fuse and release their hidden energy.

However, in incredible heat of this sort everything in nature evaporates and turns into gas—plasma. Does this mean that the installation in which deuterium is heated also turns into gas? Of course. Then it follows that the process can't be used? Fortunately, this is not the case.

The fact is that plasma is made up of particles and tiny pieces of substances: electrons, neutrons, nuclear fragments, and whole atomic nuclei. All these substances have an electric charge. Scientists can make use of this, and so they decided to "pack" the plasma in a magnetic field.

It is difficult to explain what a magnetic field is, but we shall try.

You have probably held a magnet in your hands at least once. This piece of metal attracts every piece of iron to itself: nails, thumbtacks, paperclips... And a magnet itself "sticks" firmly to iron.

In many books that you have either read or will soon read, there are descriptions of experiments with magnets and metal filings. Sprinkle a pile of iron filings onto a piece of cardboard. Lightly tap the bottom of the cardboard with a magnet. As if by magic, the pile disperses, falling into neat circles of filings. There is no magic involved, of course. The MAGNETIC FIELD has acted on the filings, distributing them along its own LINES OF FORCE.

Lines of force always exist around a magnet, whether there are any filings or not. The filings simply "show" these invisible lines, just as developer brings out the picture on photographic paper. This network of lines makes each charged particle move along a fixed path. The particles cannot fly off as they wish. The magnetic field compresses the plasma into a fine string. A vacuum is set up between this string and the walls of the installation, and therefore the walls remain safe and sound.

The magnet serves yet another useful purpose. There must be a great many nuclei for them to begin to fuse. It is easier for them to find each other this way. The magnetic field gathers all the nuclei into one "heap" in which sooner or later they collide, fuse, and give off energy. However...

All this is based only on hope for the time being. No one had yet succeeded in heating deuterium to the necessary temperature

and releasing its energy. True, Soviet scientists have designed and built a whole series of installations under the name of "Tokamak". The latest Tokamak model can provide heat up to 20 million degrees C. Only ten times less than the required temperature! The Tokamak installations still use up more energy than they produce, and they must be further developed and researched.

It is very difficult to control plasma. It searches very insistently for the slightest crack in the magnetic field and as soon as it finds one, it immediately breaks free of the field. The deuterium nuclei, for which the magnetic network was created, fly off in all directions and everything has to be begun anew.

Scientists are therefore seeking other means by which the energy in a nucleus can be released. A tiny drop of heavy water packed with deuterium atoms is frozen. The result is a grain of ice the size of a pinhead. A laser beam is directed at this piece of ice. A laser is a crystal or a thin tube containing gas which "shoots" a beam of light with great force. The force of the blow heats the piece of ice to a very high temperature. The deuterium nuclei in it begin to fuse and release their energy. A small explosion takes place. Then the laser beam is redirected at another target, then another... Explosions follow one another. Each explosion on its own releases only a small quantity of energy, but all together... Scientists have calculated that in order to obtain enough energy, at least 20 granules of ice containing nuclear fuel must be exploded per second.

The energy given off by the ice granules is used to heat liquid lithium, a metal. Lithium transmits the heat to water. Not heavy water, but ordinary water. The water turns to steam, and the steam is directed towards a turbine.

This fusion of nuclei is called a thermonuclear reaction ("thermo" means "warm" or "hot" in Latin) because of the enormously high temperature at which it takes place (200,000,000 degrees C is no joke!).

These reactions are very usual in nature—although not on Earth. Men used thermonuclear energy even before they knew they were men. A thermonuclear reactor has been hanging above our heads for billions of years—the sun.

A constant thermonuclear reaction has been taking place deep inside the sun for billions and billions of years. And all this time a powerful energy flow has been directed towards the Earth.

Natural reactors—stars—are scattered across the entire heaven. True, they are so far away that their energy hardly reaches us and is lost in boundless outer space.

A thermonuclear reaction is not only good because it provides a great deal of energy. Its second important feature is that it is clean.

Thermonuclear energy will most likely be made into electricity. True, not even a name has been thought up for these stations, but it is absolutely certain that they will exist. We do not have long to wait for them.

* * *

Here is another interesting, important plan connected with hydrogen. It is projected to replace petrol. There are at least two reasons for this.

You already know the first reason. It is very expensive to burn petrol in engines. The great Russian chemist, Dmitry Mendeleyev, said that burning oil (or petrol) is equivalent to stoking a stove with money. This is absolutely true, and it has become especially obvious today. We have already said that thousands of useful products can be obtained from oil. From cloth and medicine to caviar. Instead we are turning it into petrol, kerosene, and fuel oil. We are burning shirts, suits, machine parts, medicines, and food which never had a chance to be manufactured.

The second reason is that it has been firmly established that what remains after oil products are burned pollutes the atmosphere, and as long as we continue to burn it, the more

polluted our air becomes. In the course of one year, a car discards a ton of harmful substances in the air. They are very damaging to nature, they hold back the sun's rays, and poison the air in large cities.

There are now over 250 million cars travelling the world's roads, hundreds of thousands of airplanes in the air, and thousands and thousands of ships sailing the seas. Each of these cars, airplanes, and ships is polluting the air.

But for the moment men have no other alternative. There is no better fuel than oil and petrol at present.

This does not mean that there will never be a better fuel. Hydrogen could become a fuel. Lomonosov* knew long ago that if you join hydrogen and oxygen, you get water, and heat is released.

Scientists and engineers were interested in this. Many believe that hydrogen would be a marvellous fuel. Firstly, there are enormous reserves of hydrogen in the earth's seas and oceans. Secondly, when hydrogen is burned it does not disappear and joining to oxygen it turns into water. Hydrogen is therefore the cleanest fuel. The exhaust pipe of a "hydrogen" engine would expel harmless steam.

Hydrogen fuel can be used in any form of transport, in industry, in heating homes, and to produce electricity.

Hydrogen is now being produced from crude oil by a chemical process. This process is expensive and produces very little hydrogen.

But there is another method—an electrical one. It is called electrolysis.

A strong electric current is sent through water. It breaks the water down into hydrogen and its other components. Hydrogen is a light gas. It rises to the surface and "leaps" out of the water. It is then "caught" and stored in tanks.

A great deal of electricity is needed for this process. Therefore

* Lomonosov, Mikhail (1711-1765)—the Russian scientist in the natural sciences, a noted poet, artist, and historian.

we can only obtain hydrogen in significant quantities when there will be enough electrical energy at our disposal. And this will only come about when nuclear and thermonuclear power stations come into full operation.

This is the chain that comes into being then: a nuclear reaction—electricity—electrolysis—hydrogen, fuel for engines.

Engineers have even planned how this chain would look at work. Floating nuclear power stations would be built on the seas and oceans. The electricity they provide would go towards the production of hydrogen. This hydrogen would be pumped along pipelines to the mainland. Then this light gas would be turned into a liquid at factories and distributed by pipe or in tanks to whomever needs it.

But things are not quite this simple. Liquid hydrogen evaporates quickly even at room temperature. Therefore the tank in which it is stored must be tightly closed. But then a great deal of hydrogen steam accumulates beneath its lid and the tank explodes. Hydrogen must therefore be stored in open tanks, dewar vessels. Their secret lies in the fact that they must be open only just enough to avoid an explosion, yet to retain as much hydrogen as possible. In order to keep hydrogen loss to a minimum, hydrogen must be cooled to a temperature of 200-250 degrees C below zero. It is very difficult to build a "thermos" of this sort. Especially for automobiles, in which the storage tank should be no larger than an ordinary petrol tank.

* * *

Let us take a quick look at what we have discussed, and draw some conclusions.

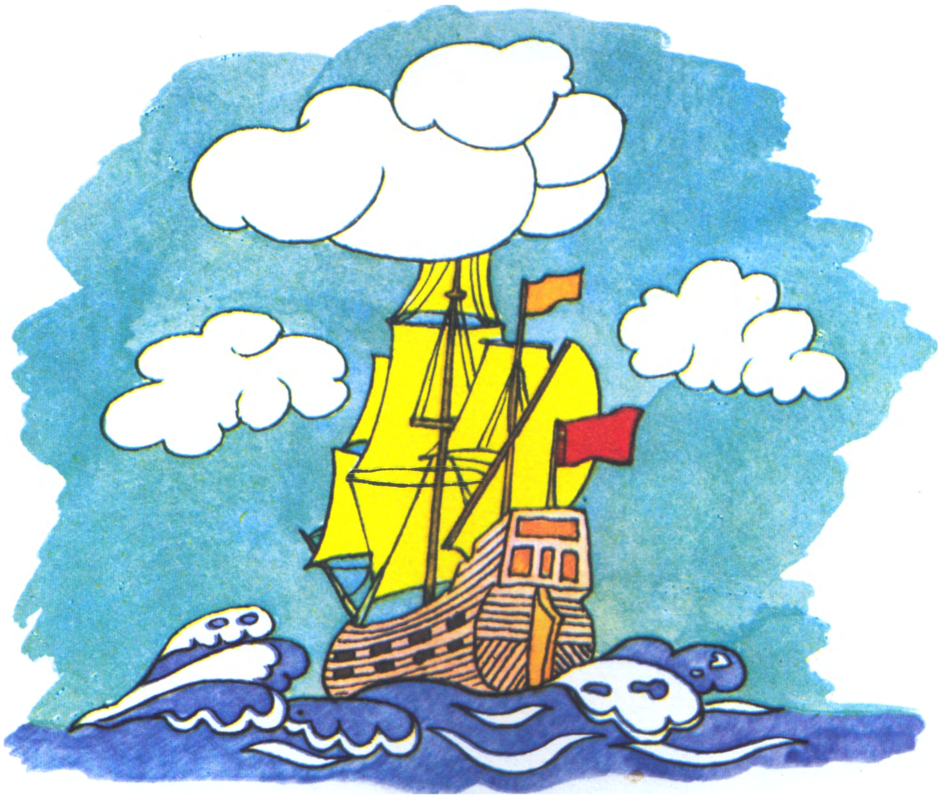
We learned about two chain processes by which energy can be obtained.

The basis of the first process is fuel. Fuel contains CHEMICAL energy. When we burn fuel, we turn this chemical energy into THERMAL energy. The fuel-based chain process of obtaining energy is the major today.

The second chain process is based on the nucleus of the atom—the storehouse of ATOMIC, or NUCLEAR energy. When we split the nucleus, we also turn nuclear energy into THERMAL energy. In the near future we shall also obtain heat from nuclear fusion. The nuclear chain process is not the major form today. But it will become major in the future.

The obligatory link in these two chain processes is heat, THERMAL energy. People cannot, and probably never will be able to do without it in either the fuel-based or nuclear methods.

These two processes, however, are not the only ones. Mankind has other sources of energy and, therefore, other processes for obtaining it. Some have been in use for a long time, while others are only now being investigated.



48 How Do We Make Use of the Energy in Water?

You have probably seen the following at some point. A stream of water flows from a wooden trough onto a wheel with blades. The wheel spins and turns a large, flat stone, a millstone. In the middle of the stone, there is an opening into which grain flows. The millstone rotates against a base, grinding the grain into flour. The stream of flour flows into bags. This is the famous watermill which fed mankind for centuries.

Another machine that you may have seen is a thick wooden axle with serrated wheels sticking out from the waterwheel. The wheels turn a drill, lift a hammer, or inflate a blacksmith's bellows. This is already a small-scale factory or a mechanical workshop.

And so the mills ground grain, and anchors for sailboats or horseshoes were forged in workshops. These small-scale enterprises did various kinds of work, and various types of machines operated in them. But the energy they needed for their machines was drawn from a single source—water.

Water's energy comes from its movement. Still water can never turn a wheel, no matter how hard we try to make it.

Men did not always understand this, however. During the Middle Ages there was a special pond in Venice where competitions between mechanics took place. They tried to put the pond's still water to work. Nothing they did, however, produced any results.The inventors explained their failure in various ways. Some said the water was too cold, others said the sun was too hot. But the main reason was altogether different: that the water did not flow...

Where do our rivers flow from and where do they go? They flow downwards from mountains and hills to the lowlands and finally to the sea. What makes them move? What force drives these

enormous bodies of water across hundreds and thousands of kilometres to the distant seas and oceans? We know the answer to this question: the pull of gravity. When water spills from a glass it always falls to the floor.

How, then, does water, which can only flow downhill on its own, get up to the mountains in the first place? What is the mighty force that pumps it up there? This force is the sun.

The sun's rays warm not only stones, sand, and plants. They also warm the water in the oceans, seas and lakes. The water turns into steam and rises high into the atmosphere; thus a billion tons of water are carried away each and every minute. When the steam reaches the air's cold layers, it again becomes water. The drops of water fall to earth in the form of either rain or snow. Here they become streams or rivers, again carrying their water down to the sea. The cycle has come full circle... This great movement is called the water cycle in nature.

Water continues to work for mankind as it has for thousands of years. True, it not only grinds grain and stokes the fire in the blacksmith's furnace. Its main task now is to produce electricity.

A river is blocked with a dam. Several pipe-like channels with enormous flaps are made in the dam. In each pipe there is a wheel with blades—an hydraulic or, simply, a water turbine. A shaft joins the turbine to an electric power generator.

When the water encounters the dam, which obstructs its flow, it begins to rise. The higher it rises, the more energy it accumulates. When the pipe's flap is opened, the water rushes towards the turbine and hits its blades with tremendous force. The turbine begins to spin. The electric generator turns with it, producing electric current.

The dam, the turbines, and the generators are called an HYDROELECTRIC POWER STATION.

The Soviet Union has many full-flowing rivers. In the European part of the Soviet Union all the major rivers—the

Volga, the Dnieper, the Kama, and other rivers—are already at work producing electricity. A whole cascade of power stations had been built along the Volga River. (A cascade is formed when power stations are built one after another along a river.) There are also a great many power stations along the Dnieper.

There is still a lot of unused energy in the Siberian rivers. Therefore, mighty power stations, as powerful as the rivers themselves, have been built there. The world's largest hydroelectric power station stands on the banks of the Enisei River, near the city of Krasnoyarsk. An even mightier hydroelectric power station, the Sayano-Shushenskaya, is now being built on the Enisei River. The location chosen for it is a deep ravine with steep banks. The Enisei has been cut across with a high dam, which will contain ten hydroelectric units. This is what a hydroturbine together with an electric generator is called.

Construction of an hydroelectric station is very expensive. But the energy it produces is the cheapest available, because its source is "free"—the Sun. Do you remember when we spoke of the sun as a pump?

Not only the sun, however, gives its energy to water. The same work is performed by our "nighttime sun", the Moon. But it does not heat water or make steam rise to the heavens. It acts through its gravitation pull.

We know that all the heavenly bodies exert a gravitation pull. This pull depends on the weight or, more correctly, on the mass of the body involved. The larger the mass, the more strongly it pulls everything around it towards itself. The further the bodies are from each other, the weaker their gravitational pull is. The nearer they are, the stronger their pull.

The Moon—our closest neighbour in outer space—exerts a strong pull on the Earth and everything on it, drawing it towards itself. It does not hang over one spot, but rotates around the Earth. As it moves, it "lifts" the objects beneath it. On dry

land this is not noticeable. But in the vast expanse of the oceans it creates a wave, and this is very noticeable. Twice daily at exactly the same time this wave runs across all the oceans and seas. Enormous quantities of water rise and fall smoothly, and on the seashores the tide rises and falls.

Lunar waves contain a great deal of energy. A hundred times more energy than produced by all the world's hydroelectric stations. True, this energy is diffused throughout the oceans' broad expanses and cannot be "caught". After all, who would build a hydroelectric station in the middle of the Pacific Ocean? But tiny "portions" of it can nonetheless be caught.

Energy is "caught" in the following way. A bay with a narrow mouth is found, then a dam is built across this mouth, and turbines and generators are installed in the dam. As the tide rises and falls water enters the pipes and rotates the turbines.

Water usually rises three or four metres, but there are spots in which the tide rises as high as a building. The higher the water rises, the harder it strikes the turbine's blades and, consequently, the more energy it provides. Soviet scientists believe that a tidal station three times as powerful as the Krasnoyarsk Hydroelectric Station could be built in the northern part of the Sea of Okhotsk, where the Penzhina River flows into the sea.

The first tidal stations located on the seashores have already been built in France and the Soviet Union. True, the station located on the Kola Peninsula does not produce a great deal of power. But Soviet engineers and scientists have already elaborated new plans for tidal stations on the shores of the northern seas to provide the northern and eastern regions with the energy they need more and more with each passing year.

* * *

Do you remember what we said about the medieval mechanics who tried to make still water work? And how they failed? Well,

not long ago Soviet scientists thought up a plan to do just this.

An enormous cylinder is lowered deep into the sea or into a large lake. One or more pipes with slide-valves are installed in the cover on the cylinder. Inside the pipes there are power units. When the slide-valves are opened, water flows into the cylinder through the pipes, passes through the turbines and starts them rotating. The turbines will continue to rotate until the cylinder is full. Then the hydroelectric units stop.

Why should such stations be built if they cannot work all the time? A great deal of energy is needed in the peak hours: early in the morning when work begins at factories and in the evenings, when lamps in houses, street-lamps, and television sets are switched on. But at night very little energy is used.

In the morning and evening all the generators at hydroelectric stations work at full capacity, but they still cannot provide enough energy. At night most of the hydroelectric units stop working because their energy is not needed. The underwater electric power stations will help the stations on land during the peak hours. But preparations must first be made and the water pumped out of their cylinders. This can be easily done with electric pumps at night, when there is power to spare at the hydroelectric stations. The underwater stations thus provide a back-up reserve of electric power.

By now you have understood that neither fuel nor water make energy of themselves. They are only "reservoirs" of the sun's energy.

Could we get by without them? Could we obtain energy directly from the sun? Yes, we could. Read on and learn how.

"Let there always be sunshine," goes the children's song. It's wonderful when it's sunny, when it's bright and warm, when you can swim and get a suntan, when there are juicy apples and sweet, red watermelons.

But the sun is not only for getting a suntan. This is the least that it does. It has more important things to do.

The sun's energy is the basis for every living thing on Earth. The sun's rays cause buds to open, fruits and wheat to ripen, trees to stretch their branches skywards, and the earth to be covered with a green carpet of grass.

But in the deserts, where there is no water, the sand grows red-hot and the stones crack beneath the sun's baking rays. Here the sun's life-giving energy becomes destructive.

It is not only in the deserts that we find "superfluous" solar energy. Not every sunbeam finds its way to a blade of grass or a leaf. The sun also heats the asphalt on city streets and the roofs of houses. For a long time men have thought about how to put this "extra" energy to use.

Many different types of solar devices have been made or built. The simplest is the magnifying glass, which everyone has probably held in their hands at some point. It concentrates the sun's light into a thin ray, and this ray can cause a piece of wood or a strip of paper to smoke. The larger the glass—the lens—the more powerful the needle of sunlight. A small lens is enough to burn a hole in your trousers. To set a teapot boiling on a clear day, the lens would need to be as large as a tractor wheel. And to boil a pail or barrel of water? You would need a very large lens to do this.

But this is not really the best way to catch the sun's energy.

You have probably heard of the solar batteries which provide

electric power for spaceships. Maybe you have even seen sketches of them. They are in the form of open-work grills shaped like wings and they are made of special materials—semiconductors. When hit by solar particles they produce electricity.

These solar batteries serve to charge ordinary batteries like the batteries in cars. And so there is always electric power on spaceships.

Solar batteries do not work very well yet. Only one-tenth of the solar energy they catch is transformed into electricity. They are therefore only used in outer space, where the energy cannot be obtained by any other means.

But if these batteries would work even three times better, they could be put into use on Earth. Solar power stations could be built in deserts. The hot sand could be covered with a vast semiconductive "blanket". The sun's rays would give its energy to this "blanket" and the energy would be turned into electric current. This current would be collected at stations and transmitted by electrical wires to homes, schools, and factories.

Not all the energy the sun sends to us, however, reaches the earth's surface. Our planet is enveloped in a thick layer of dense atmosphere and clouds. Scientists are preparing to launch a "semiconductive" power station into outer space, where there are no obstacles to the sun's rays. The electricity produced by this station will be turned into a powerful radiowave beam and directed towards Earth. On Earth this beam will again become electric current.

Scientists are considering yet another "solar" project, one that is suggested by nature itself.

You already know that the Sun is a source of energy for plants and animals. The leaves of trees and blades of grass greedily absorb the sun's rays. Their energy causes substances in plant cells to turn into other substances, which accumulate energy. Not solar, but chemical energy. We use this energy when we eat

 bread and drink milk. Food is also a source of energy for people. Just as the sun is a source of energy for plants.

If only we could learn from the plant cells how to use sun energy as they do. Then we could create artificial "cell-factories" a billion times more powerful than living cells.

Then amazing fields of energy could appear in the deserts, or anywhere where there is a great deal of sun. Just imagine—transparent pipes snake across the desert sands beneath the hot southern sun. Rivers of "living" or, as chemists say, organic solutions flow through the pipes. The same solutions that are found in plant cells. They greedily absorb the sun's rays, and new substances come into being, substances "charged" with chemical energy. Pumps take the solutions to factory floors. There they are passed through filters and their energy-rich components are collected. Having collected this "harvest", the needed substances are added to the solution and it is again sent off in search of energy.

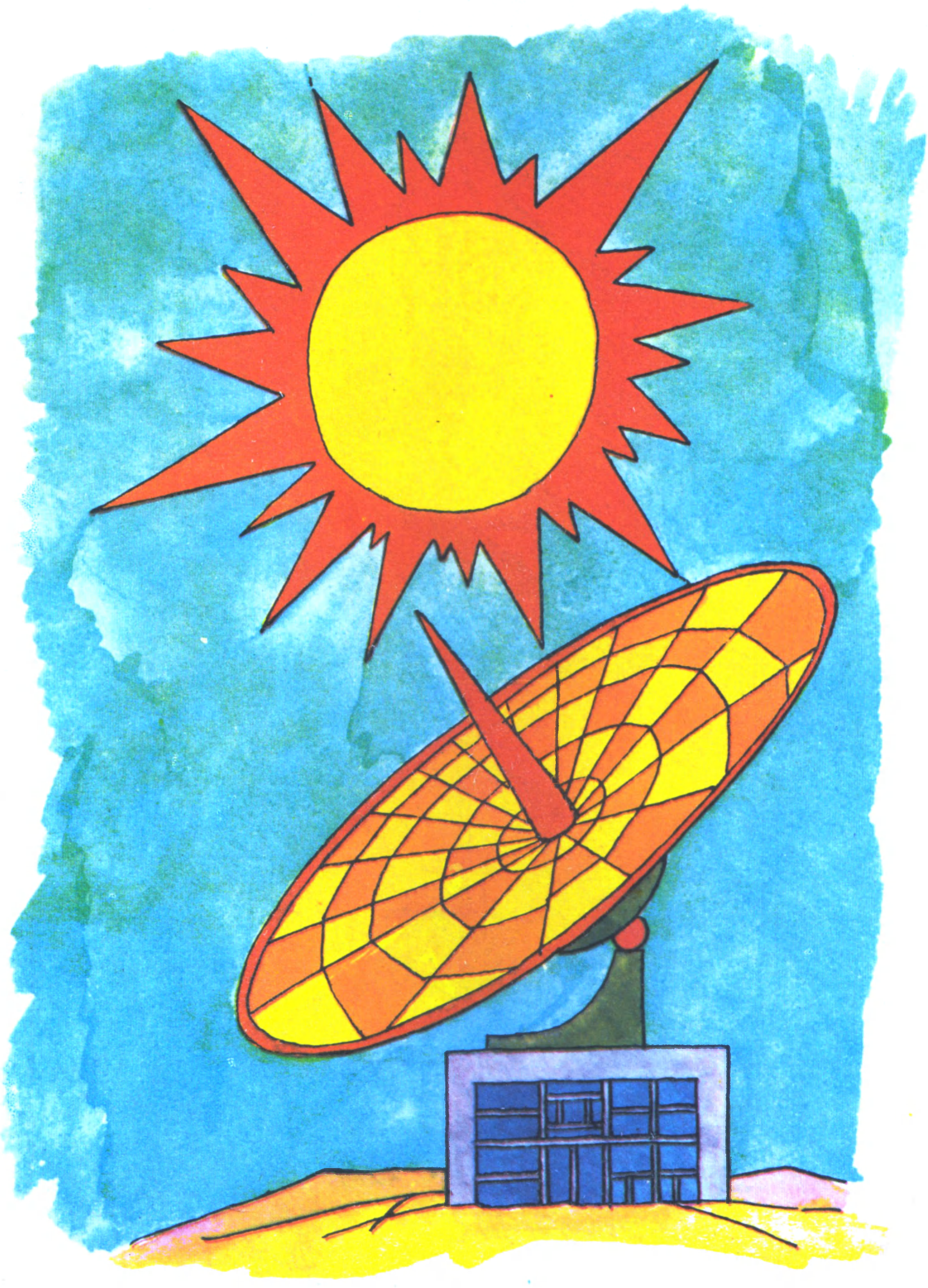
Since time immemorial men have repeated this cycle doing almost the same thing. Seeds are planted in soil and people wait for the plant to grow, ripen, and accumulate nourishing substances in its cells from the sun's rays. Then the plant is picked and its seeds are gathered for future harvests. Either the "tops" (the seeds of wheat, rye, or tomatoes) of the plant or its "roots" (potatoes, carrots, or beetroot) are eaten.

A great deal of space is required for artificial "solar" fields. The earth has this space. In Africa there is the Sahara Desert, in Asia, the Gobi Desert, and in the Soviet Union, the Kara Kum Desert.

Can mankind obtain a lot of energy from these solar "gardens"? Yes, a great deal indeed—sixty times more than we obtain from all the fuel being extracted now.

Moreover, a solar "addition" to fuel and nuclear reserves would not be harmful to nature. Solar energy does not pollute the atmosphere, water, or soil.

A very attractive prospect, isn't it? But are these just dreams? For the time being, yes. But scientists are already at work on them. And since the problem is tackled seriously, the solar fields are near at hand.

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"The red light of the indicator flashed on the control panel of the Pioneer spaceship, and the alert signal immediately began to wail. The pilot on duty pressed the communications button linked to the ship's computer. An imperturbable electronic voice said: 'Unknown body directly ahead. Distance one and a half parsecs. Body moving in a circular orbit around a star 200,000 kilometres in diameter. Further details to follow...' The pilot switched on his microphone and quickly announced: 'Commander requested in main control room...' An unknown body, a mysterious star. An encounter with an unknown world awaited the expedition..."

Something similar to this can be read in almost any book about future space flights. Discovery of a new planet where the grass is lavender, the sky black, and stars twinkle mysteriously. When you read books like this it seems that all mysteries are to be found in outer space. Yet a very important mystery, perhaps the most important one, exists beneath our very feet—deep inside the Earth.

Men have succeeded in flying hundreds of kilometres above the Earth. They have flown to the moon and launched automatic stations towards Mars and Venus. Yet they have not yet been able to go deep into the Earth. They have only managed to take a peep beneath the Earth's surface at a depth of more than 13 kilometres in a few scattered spots. But what goes on deeper than this? What happens in the very centre of the Earth?

The Earth is like a nut with a hard outer shell. This shell is called its crust, and its centre is burning hot. The temperature is higher at the Earth's centre than in a furnace. This means that everything in the Earth's centre is molten. The closer one gets to the surface, the cooler the temperature. But at a depth of 20 kilometres the temperature is still very high—600 degrees C. The molten mass exerts great pressure on the crust, as if trying

to break through it. It is even able to rise to the surface along cracks in the crust. If it encounters water as it pushes upwards, the water instantly boils, turning to steam and emerging through the crust in the form of warm springs.

A great deal of precious fuel is used up in heating and boiling water. But here if pipes are installed, this hot water can be channelled to cities and villages. In fact, it is done in many areas.

In addition, the underground steam and hot water are channelled through pipes to electric power stations. The steam is piped to turbines and sets them in motion, and the electric generator produces electricity. Just like with an ordinary thermal power station. Only in our case steam cauldrons are not needed, for they already exist in the bowels of the earth. Electric power stations of this type are called GEOTHERMAL stations, this is, their raw material is the Earth's own heat.

The first such station in the Soviet Union was built on the Kamchatka Peninsula. In 1966 it provided electricity and heat to the fishing settlement of Ozernaya. Heat is provided to homes and greenhouses, and the settlement's inhabitants eat spring onions, parsley, and cucumbers nearly all year round.

Stations of this type are being built in other countries, as well. A whole lake of hot water was recently discovered in France just under Paris. Scientists are now deciding where this water can best be used—in Paris flats or at electric power stations.

We do not have to find hot springs or lakes to make use of the underground cauldrons. Engineers are proposing to create them with their own hands.

Two shafts are drilled deep inside the earth and are joined by an underground canal deep below the surface. Cold water is pumped into the hot layers of the earth through one shaft, and hot water and steam rise to the surface through the second shaft. There is underground heat everywhere beneath the earth's surface: beneath Moscow, beneath the Sahara, and beneath the

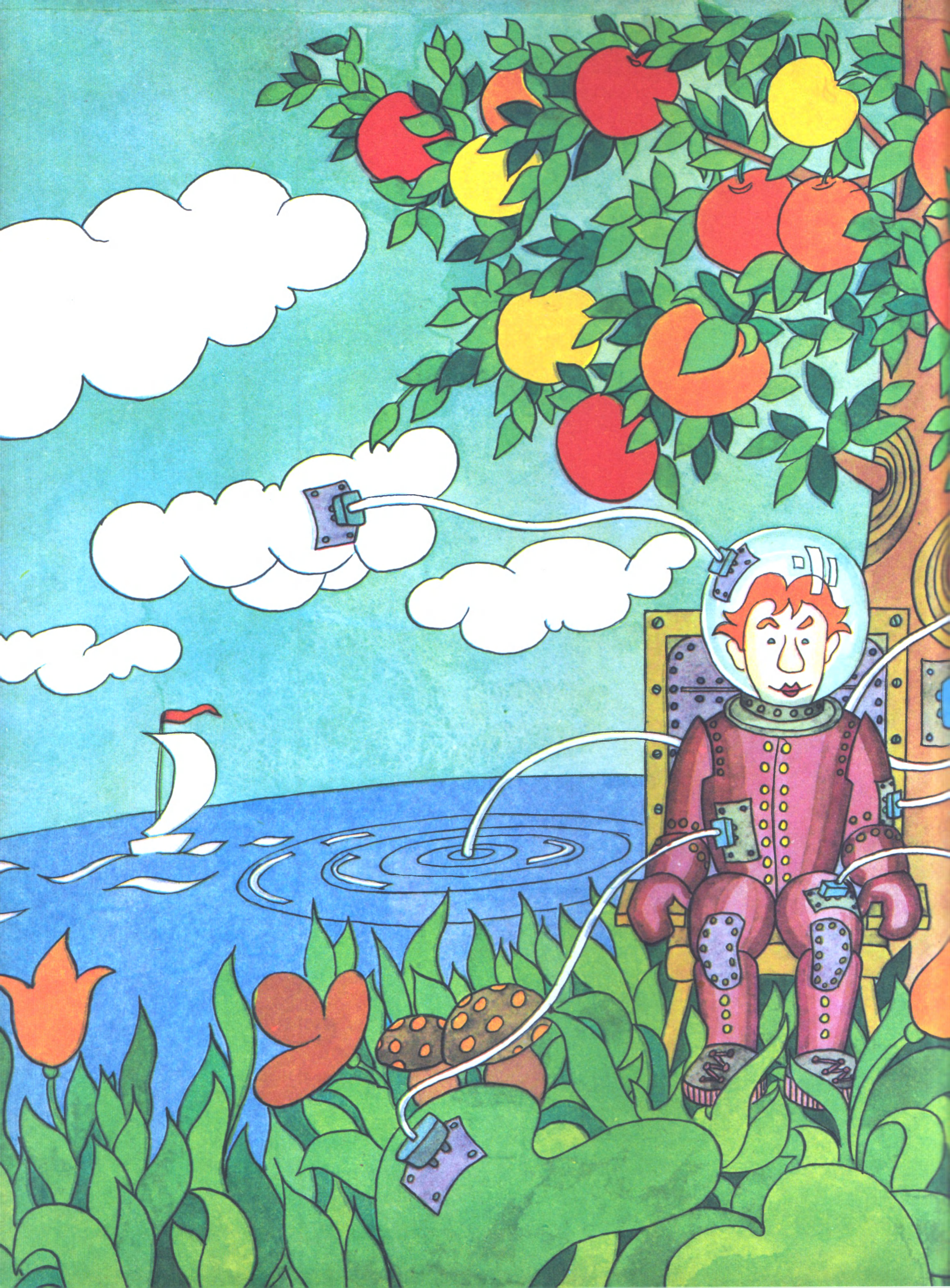
tundra. The tundra, as we all know, has "12 months of winter and the rest is summer", as the saying goes and so the Earth's heat is needed here more than anywhere else. Yet this is only a tiny fraction of the energy concealed in the Earth's core. If we can get through to it, people would not have to worry about energy and warmth for thousands of years to come.

It is much harder to do this, though, than to fly into outer space. Shafts have so far only enabled us to peek into the earth's depths. These shafts are drilled into the earth with enormous bits. The steel pipes with a mechanical tooth—the bit—rotate slowly for several kilometres, going deeper and deeper into the earth. But the long column of pipes will break under its own weight if the depth is great indeed. Something entirely new must be thought up for serious explorations underground. Perhaps a special underground vehicle.

Engineers were able to build an underground vehicle of this type in the Soviet Union, patterning it after the habits of moles. A mole loosens the earth with his sharp teeth, then rams it by turning his head and quickly moving on.

The mechanical "mole" was equipped with hard metal teeth, a strong, rotating "neck", and a powder-run engine. During tests it went very deep—up to 7 kilometres underground.

It may just be then that one day we shall read about an expedition to the centre of the Earth on a vehicle of this sort in our daily newspaper, rather than in a work of science fiction.



Have you noticed that in nearly every chapter we have mentioned electricity? Whether speaking of thermal energy, atomic energy, or water energy, we always come to an electric power station at the end.

A third of thermal energy goes towards the production of electricity. All the energy we obtain from rivers is turned into electricity. Nuclear energy, too, is only needed if we turn it into electric energy. And this is not accidental.

Electricity is the most "capable" form of energy. It can do everything or almost everything.

Our age has been given different names: the nuclear age, the rocket age, the space age. But the most accurate name would be "the electrical age".

We do not have to prove this. Just look around you. Our homes have electric irons, vacuum cleaners, television sets, radios, electric razors, electric light, and elevators. On the streets we have trams and trolley-buses. Electrical suburban trains travel the railroads, in cities there is the subway. Electricity means billions of engines at work in factories, electronic computers, and so on. If electricity suddenly disappeared, our life would be terribly hard.

There is no immediately useable electricity to be found in nature. Occasionally a lightning bolt strikes and thunder fills the air, but once it's over, that's it. Electricity cannot be obtained "ready-made" from natural sources, like coal, gas, or hydroenergy can be. Electricity came into being through man's ingenuity.

Long ago Professor Luigi Galvani was delivering a lecture at home to his students. His wife stood by the fireplace skinning frogs for dinner with a steel knife, then placing them on a tin plate. Listening to her husband, she dropped her knife. It fell on

the leg of a skinned frog, one end of it touching the plate. The frog's leg jumped as violently as if it wanted to leap out of the plate. Galvani's wife told her husband what had happened. He repeated this experiment with the frog's leg many times and decided that he had discovered "animal electricity". According to his theory, this electricity was to be found in living bodies and guided the work of the muscles and brain.

But the real answer to this puzzle was discovered by the outstanding physicist, Alessandro Volta. He did not believe in "animal electricity" and regarded the frog in Galvani's experiments as incidental. The electric current, Volta said, was a result of contact between two different metals—steel and tin. The leg was simply a conductor, just like an ordinary copper wire. Nine years later he proved this in practice. He built a voltaic pile, which he called a galvanic element in honour of Galvani.

These elements helped scientists to study the secrets of electricity for many years. They provided electric current for the first electromagnets. The Russian physicist, Vassily Petrov, lit the first electrical source of light—the voltaic arc—from them.

But Volta's elements were very weak. High, cumbersome towers had to be built to provide enough electricity. That is why they were called "piles".

At the beginning of the 19th century, the owner of a bookbinding workshop in London took a fourteen-year-old boy as an apprentice. The son of a poor blacksmith, this boy had not even completed primary school. But he was curious and loved to read. The boy's name was Michael Faraday. One day, while he was binding a volume of the Encyclopaedia Britannica, he read an article on electricity. Its marvellous qualities amazed him. He began to build various electrical apparatus out of scraps of metal and wire and to carry out experiments with them.

Michael Faraday discovered that a magnetic field always grows up around a conductor with electric current. Do you

remember the circles of metal filings? Well, this is the same thing. "Electricity is transformed into magnetism!" scientific journals wrote at the time.

If electricity could be transformed into magnetism, Faraday wondered, then why couldn't magnetism be turned into electricity? To constantly remind himself of this, he put two magnets in the pocket of his frock-coat. Faraday made hundreds of experiments and built dozens of instruments. Finally, after nine years of experiments, in 1831, a sketch was published in a scientific journal. The drawing showed a thin copper disc between two magnets. Alongside was a magnetic needle. When the disc turned, the magnetic needle moved. When the disc stopped, the needle returned to its initial position. Faraday explained that when the disc rotated the magnets created electricity in it. The electricity makes "magnetism", and the needle moves. Please note: "when the disc rotated". If there is no rotation, there is no electricity. We now speak about it in this way: the MECHANICAL energy of the motion is transformed into ELECTRICITY.

Faraday's instrument was called an ELECTRO-MECHANICAL generator. That is, an instrument which makes electric energy from mechanical energy. True, a real generator was built thirty years later. But Faraday's experiments laid the path to modern electrical energetics. Today nearly all electricity is produced by electro-mechanical generators. They have different names. If a generator rotates from a steam turbine, it is a turbogenerator. If it is turned by a water turbine, it is a hydrogenerator. But this doesn't change the nature of the machine. True, modern generators do not have a copper disc, as Faraday's machine did. But electricity is still produced in the copper wires which rotate in a magnetic field.

In 1838, several years after Faraday's discovery, the Russian scientist Boris Jacoby invented the first electrical engine. His electrical engine did everything the opposite way. It turned the

electric energy into motion. Jacoby installed it on a boat, called "Jacoby's electric boat", and tested it on the Neva River. Newspapers of the day wrote: "The boat with 12 passengers impelled by electro-mechanical force ... sailed against the current for several hours, in the face of a strong wind..."

These two discoveries can be regarded as the beginning of the age of electricity.

Like everything new, electricity did not win immediate recognition. It only gained people's confidence after the "Russian light"—Yablochkov's streetlamps—were lit up on the streets of Paris in 1876.

What is electricity? Textbooks write that the electric current is a flow of electrons. Do you remember how an atom is structured? In the centre there is the nucleus around which electrons whirl as if bound to it. However, the electrons are not all "tied" to the nucleus in exactly the same way. Some are strongly tied and others are not. The electrons that are weakly tied create electric current. They leave their atom easily and become "travellers". We find an especially large number of free electrons in metals, where they wander at will. They join other atoms, then set off again on their wandering path. But this carefree movement is still not electric current. Electric power is generated when all the free electrons begin to move in one direction like cars on a one-way street. The cars are driven by people, and the electrons in the wires of an electro-mechanical generator are driven by magnets. They cause all the electrons to move in one direction.

Electricity has carried out a genuine revolution in people's lives.

Steam machines became obsolete and were replaced by electric engines. An electric wire furnishes the energy, and the electric engine transforms it into motion. True, it still couldn't compete with the petrol engine on such means of transport as aeroplanes and automobiles. After all, neither the plane nor car can drag an electric wire after them. A solution was found for

 public transport, though. Electric wires were strung above railway lines and streets. Current collectors were installed on the roofs of trains, trams, and trolley-buses. As current from the electric generator flows along the wires, the current collector (arc) also slides along them—and the engine turns the wheels.

Need anything be said about how electricity has changed our ordinary domestic life? Could we live without the electric light bulb? Or without the TV set, washing machine, floor-polisher, lift, or telephone? We could, of course, get by without them, but life would be much harder and more tedious. We could never go out to a movie or turn on the radio.

The most important thing isn't the movies, of course. Electricity is the main form of energy for our industry.

People use three "chains" to obtain electricity.

The most important chain is the one based on fuel. The second chain is the one in operation at hydroelectric power stations. Nuclear power stations occupy third place.

This does not mean that things will continue this way forever. In twenty or thirty years the picture will change. Nuclear power stations will produce half of our electricity. People will save fuel, which even today is in short supply. Thermal power stations will be a rarity. Just like steam locomotives are today.

Electricity flows from the power stations like a river. And, like a river, it has a channel—the electric wire, and a source—the electric generator. Like a river, electricity contains a charge of energy and makes all sorts of machines work: mills, electrical hammers, and factory equipment... A real river is made up of thousands of tiny streams and brooks. But electric current, on the contrary, is broken up into rivers, streams, and brooks. At first a powerful, full current emerges from the power station onto the lines of the electrical transmissions. You have probably seen these lines on their high supports on the outskirts of towns, in forests and in fields. Then it is divided up at sub-stations. Part of it goes to the city, and the rest of it goes to the villages and

small towns. The city's electricity is again divided up according to districts, and the district current is broken up for the factories and streets. And so on, right down to the smallest table lamp, television set, or engine on a factory machine. At the end of its journey, electricity is turned into light, a picture on the screen, the motion of a bit or a milling cutter, into the heat from an electric heater or a smelting furnace.

Electricity improves our lives greatly, yet it has its negative aspects. Firstly, the method by which it is obtained is inconvenient: the "chains" are very long, especially in the thermal method of producing electricity.

Energy must alter its form many, many times before becoming electricity. First fuel is burned and releases its heat. Then water is boiled in steam cauldrons to make steam. The steam's pressure is turned into motion. Only after this do we get electricity. This "chain" is exactly the same today as it was a century ago. A great deal of energy is lost along this path. This is a wasteful process for both mankind and nature. One out of two tons of fuel is wasted in the process of producing electricity. Thermal machines cannot be improved. Therefore, scientists and engineers have decided, these machines should be removed from the "chains". Heat should be turned directly into electricity. So new machines have been built—magnetic hydrodynamic generators. "Hydro" means "water". But in fact, there is no water in them. There is only white-hot gas—plasma. We already know that it is made up of a multitude of electrically charged particles. The gas is passed between magnets, which separate the particles. The positive (+) ones go to one side, and the negative (-) ones go to the other side. The particles are collected on two discs. If these discs are joined by a wire, electric current will travel along it. Then everything follows its usual course.

But in practice things turned out to be much more complicated. It is hard to turn enormous masses of gas into plasma. A very high temperature and a lot of fuel is required. There are many

other complications, too. That is why there are still very few such stations.

The second problem with electricity is linked with its transmission. The main "rivers" along which electric current flows today are electrical transmission lines. A lot of energy is lost in them, they take up a lot of space, they are expensive and, just like a narrow city street, they are limited in the amount of "traffic" they can let through at any one time. We need increasing amounts of energy and it will be necessary to build more and more of these transmission lines.

Engineers are now proposing a new method: transmitting "frozen" energy. Some materials transmit energy without any loss when they are well-frozen. A slender frozen strand can transmit as much energy as a cable as thick as a log. This means that enormous networks of transmission lines would not be needed in the future. Expensive copper would be saved, the consumer would receiver more electricity and large spaces around the transmission lines would be freed for crops.

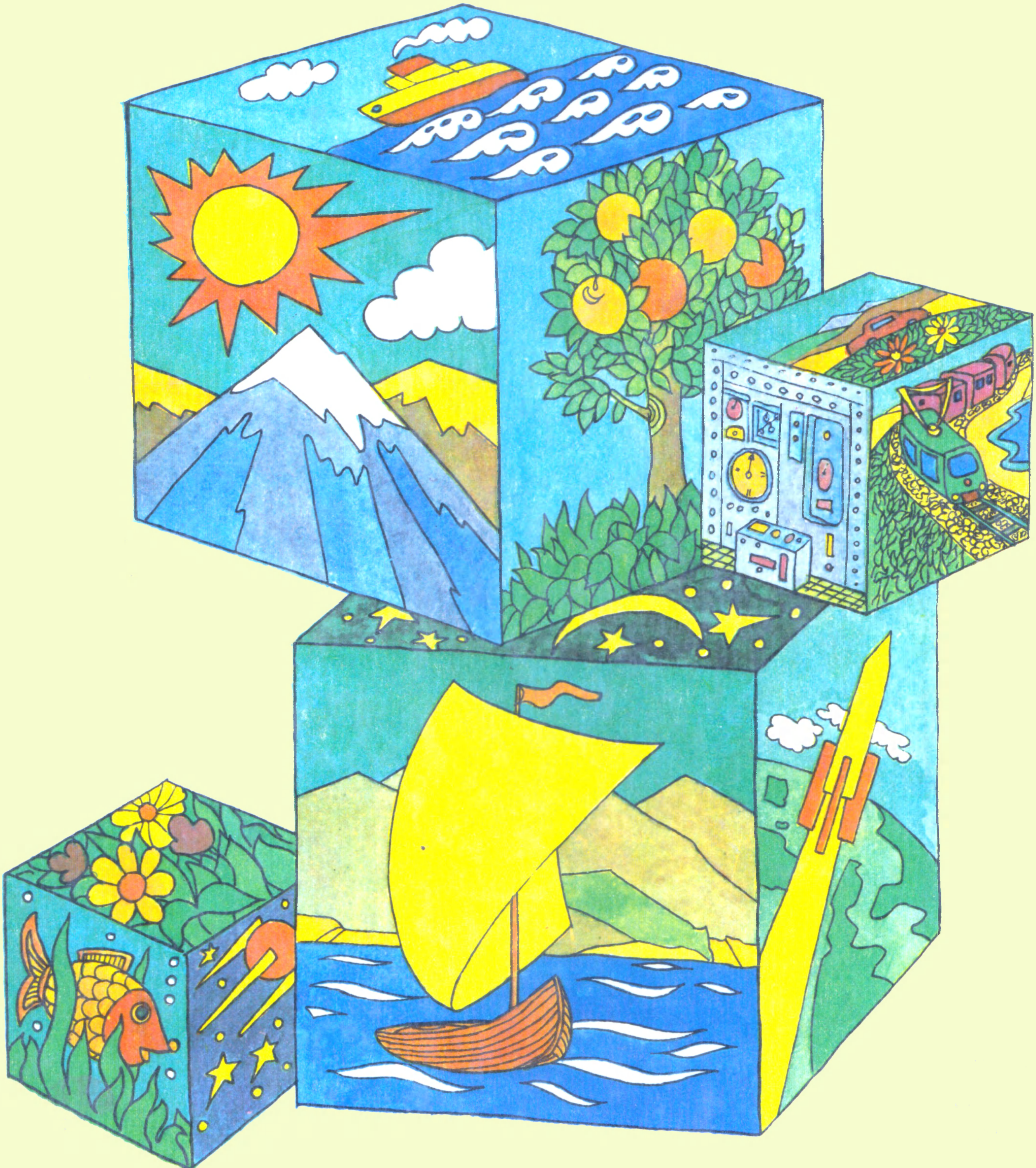
Wires are frozen with the liquid gas helium. The wire is pulled into a metal pipe and helium is pumped into it. It is a real possibility that our present aerial "rivers" of electricity will soon be replaced by underground "rivers".

* * *

On this we end our book. We admit that we could not tell about everything, nor did we intend to: ours was too short a book to allow this, and, besides, serious scientific literature deals with these complex topics in greater detail.

Our only aim was to give readers a brief acquaintance with a world that is very important to mankind, the world of

POWER ENGINEERING.



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